ARO 24649.9-EL-S

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# A Novel Communication Network Simulator

Axiomatix

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# A Novel Communication Network Simulator

Interim Technical Report

Prepared for

U.S Army Research Office
P. O. Box 12211
Reseach Triangle Park, NC 27709-2211

Contract No. DAAL 03-87-C-0007

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Axiomatix Report No. R9003-3
March 31, 1990

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

# REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION
Unclassified

1b. RESTRICTIVE MARKINGS

2a. SECURITY CLASSIFICATION AUTHORITY

2b. DECLASSIFICATION / DOWNGRADING SCHEDULE

3. DISTRIBUTION / AVAILABILITY OF REPORT
Approved for public release;
distribution unlimited.

4. PERFORMING ORGANIZATION REPORT NUMBER(S)
R9003-3

5. MONITORING ORGANIZATION REPORT NUMBER(S)
ARO 24649.9-EL-S

6a. NAME OF PERFORMING ORGANIZATION
Axiomatix

6b. OFFICE SYMBOL *(If applicable)*

7a. NAME OF MONITORING ORGANIZATION
U. S. Army Research Office

6c. ADDRESS *(City, State, and ZIP Code)*
9841 Airport Blvd., Suite 1130
Los Angeles, CA 90045

7b. ADDRESS *(City, State, and ZIP Code)*
P. O. Box 12211
Research Triangle Park, NC 27709-2211

8a. NAME OF FUNDING / SPONSORING ORGANIZATION
U. S. Army Research Office

8b. OFFICE SYMBOL *(If applicable)*

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
DAAL03-87-C-0007

8c. ADDRESS *(City, State, and ZIP Code)*
P. O. Box 12211
Research Triangle Park, NC 27709-2211

10. SOURCE OF FUNDING NUMBERS

| PROGRAM ELEMENT NO. | PROJECT NO. | TASK NO. | WORK UNIT ACCESSION NO. |
|---|---|---|---|
| | | | |

11. TITLE *(Include Security Classification)*
A NOVEL COMMUNICATION NETWORK SIMULATOR

12. PERSONAL AUTHOR(S)
Unjeng Cheng

13a. TYPE OF REPORT
Interim

13b. TIME COVERED
FROM ________ TO ________

14. DATE OF REPORT *(Year, Month, Day)*
1990, March 31

15. PAGE COUNT
6

16. SUPPLEMENTARY NOTATION
The view, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

17. COSATI CODES

| FIELD | GROUP | SUB-GROUP |
|---|---|---|
| | | |
| | | |

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
Direct-Sequence, Frequency-Hopping, Jamming, Networks, Packet Radio, Simulator, Spread-Spectrum

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

This report presents the theoretical background of the Network Simulator, which is used for investigating the performance of communication networks under various jamming threats. To demonstrate the operation of a communication network under various jamming scenarios, we provide two spread-spectrum models: direct-sequence and frequency-hopping. The use of the spread-spectrum physical layer is to provide adequate anti-jamming capability. A salient feature of the Network Simulator is its capability to simulate the nonstationary jamming strategy. This is important because analytical models of nonstationary jamming do not exist.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION
Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL
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22c. OFFICE SYMBOL

83 APR edition may be used until exhausted.
All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

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## 1. Introduction

This report presents the theoretical background of the Network Simulator, which is used for investigating the performance of communication networks under various jamming threats. It has many useful features:

(1) A network editor lets you create and edit the network easily.

(2) A jammer editor lets you create and edit the jammers easily.

(3) The route between any source-destination pair and the measured link quality can be displayed during simulation.

(4) Two propagation loss models are provided, viz., the square-law loss ana power-of-four loss models.

(5) Two spread-spectrum models are provided, viz., the direct-sequence and frequency-hopping models.

Using this simulator, we are able to show that a fully-connected network may become partially connected when the jammer power is strong. This phenomena are more prominent for the power of four loss model than the square-law loss model. For the power-of-four loss model, the received signal and jamming power both decrease fast as the distance increases. Therefore, each jammer can only affect the nearby nodes and it is also more difficult for each communicator to talk to the jammed nodes far away from it.

We implemented the routing algorithm for the Packet-Radio (PR) network in the simulator since the algorithm is well-known and contains two important features:

(1) automatic link quality measurement, and

(2) automatic routing table computation.

The link quality measurement is done in two stages:

(1) Each receiver keeps track of the number of correctly-received packets from each of its neighbors. Each transmitter keeps track of the number of packets transmitted to each of its neighbors.

(2) When exchanging the routing information, the receiver notifies each of its neighbors of the number of correctly-received packets. The link is considered good if the percentage of the correctly-received packets exceeds 75%.

Note that for a fully-connected network without jamming, the routing algorithm will choose the one-hop operating scenario automatically. When the jammer is on, the algorithm will adopt the multi-hop operating scenario automatically if some links become bad.

## 2. Spread-Spectrum Models

To demonstrate the operation of a communication network under the various jamming scenarios, we provide two spread-spectrum models: direct-sequence and frequency-hopping. The use of the spread-spectrum physical layer is to provide adequate anti-jamming capability. Among various spread-spectrum systems and jamming techniques, we consider only two cases here. They are discussed in the following.

### 2.1 Direct-Sequence System

For the direct-sequence model, we assume the jammers are full-band noise jammer. The jammer k has the average jamming power $J_k$ and it is on in a slot with probability $P_k^{(J)}$. For a node at distance $r_k$ away from the jammer k, the received jamming power in a time slot is given by

$$J_k^{(R)} = \begin{cases} \dfrac{J_k}{r_k^m P_k^{(J)}} & \text{with probability } P_k^{(J)}, \\ 0 & \text{with probability } 1 - P_k^{(J)}, \end{cases}$$

where m = 2 for the square-law loss and m = 4 for the power of four loss.

We assume that all communicators have the same transmitting power S. The packet transmitted by node i will be received by node j with the signal power:

$$S_{ij}^{(R)} = \frac{S}{r_{ij}^m}$$

In this version of the Network Simulator, we assume BPSK modulation and no coding. Although we do reserve the data fields for the error correction code definition in the system parameters data form, the code is not used in the simulation.

There is a simple formula for computing the packet error probability in the DS model. The simulator can determine whether a received packet is received correctly without any symbol level manipulation. Therefore, we can use the real packet length in the simulation.

## 2.2 Frequency-Hopping System

The frequency-hopping model assumes the partial-band tone jamming and the M-ary Frequency-Shift-Keying (MFSK) modulation. We also assume there is one jamming tone per modulation band. Let F denote the fraction of the band being jammed. The jammer i has the average jamming power $J_i$ and it is on in a slot with probability $P_i^{(J)}$. For a node at distance $r_i$ away from the jammer i, the received jamming power in a time slot is given by

$$J_i^{(R)} = \begin{cases} \dfrac{J_i}{r_i^m P_i^{(J)} F} & \text{with probability } P_i^{(J)}, \\ 0 & \text{with probability } 1 - P_i^{(J)}, \end{cases}$$

where m = 2 for the square-law loss and m = 4 for the power-of-four loss. We assume that all communicators have the same transmitting power S. The packet transmitted by node i will be received by node j with the signal power:

$$S_{ij}^{(R)} = \frac{S}{r_{ij}^m}$$

The frequency-hopping receivers operate as follows: The largest and the second largest outputs among the M filters are selected. The ratio of the largest output to the second largest output is compared to the threshold. If it is larger than 2, we accept the filter with the largest output. If the ratio is less than 2, we erase the symbol. An M-alphabet Reed-Solomon (RS) code is used to correct the errors and erasures.

Since there is no simple formula for computing the packet error probability. The FH model uses the symbol-by-symbol simulation: The simulator first determines that each received symbol is correct, erased, or wrong. Then it determines whether the received packet can be decoded successfully. The computation requirement for the FH model is significantly greater than the DS model. In order to simulate the network operation in a reasonable speed, we chose a short packet length for the FH model.

## 3. Nonstationary Jamming Model

A salient feature of the Network Simulator is its capability to simulate the nonstationary jamming strategy. A way to create a nonstationary jamming is to partition the time into blocks. Within each block of time, all jammers do not change their jamming power or jamming probability. One or more jammers can change their jamming power and/or jamming probability from block to block. This version of the Network Simulator allows you to define up to 10 jamming blocks. The duration of each block can be chosen arbitrarily. The simulator plays the jamming strategy repeatedly. When it starts, it begins with the first block and plays the blocks in the incremental order. After it finishes the last block, it goes back to the first block.